Marine Physical Laboratory

Observations of Coherent Structures in the Oceanic Boundary Layer

Robert Pinkel and Jerome Smith

Supported by the
Chief of Naval Research
Grant N00014-93-1-0359

Final Report

MPL-U-3/97
March 1997

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University of California, San Diego
Scripps Institution of Oceanography

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. Agency Use Only (Leave Blank).

2. Report Date.
March 1997

3. Report Type and Dates Covered.
Final Report

4. Title and Subtitle.
Observations of Coherent Structures in the Oceanic Boundary Layer

5. Funding Numbers.
N00014-93-1-0359

Project No.
Task No.

6. Author(s).
Robert Pinkel and Jerome Smith

7. Performing Monitoring Agency Names(s) and Address(es).
University of California, San Diego
Marine Physical Laboratory
Scripps Institution of Oceanography
San Diego, California 92152

8. Performing Organization Report Number.
MPL-U-3/97

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Office of Naval Research
Ballston Centre Tower One
800 North Quincy Street
Arlington, VA 22217-5660
Louis Goodman, ONR 322PO

10. Sponsoring/Monitoring Agency Report Number.

11. Supplementary Notes.

12a. Distribution/Availability Statement.
Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract (Maximum 200 words).

The focus of the Marine Boundary Layer program is on the role of coherent structures in the air-sea boundary layers. As an aspect of MBL, our group was funded to make observations in the ocean mixed layer, the thermocline below, and the lower atmospheric boundary layer. Our specific objectives included the study of the wind field and wind stress and their relation to the underlying surface wavefield. The particular focus is on the role of turbulent eddies in the atmospheric boundary layer which are coherent with the underlying wavefield. This involved the study of Langmuir cells and their role in mixed layer evolution. Also, the study of thermocline shears, including those not forced by local winds, and their role in the entrainment deepening of the mixed layer were also studies. These studies took place during the course of two cruises on the Research Platform FLIP, in winter-spring 1995 The first experiment was conducted 35 km west of Point Arguello, CA, in 1 km water. The site was in a semi-permanent offshore jet, with strong steady currents toward the west-northwest.

14. Subject Terms.
air-sea boundary layer, surface wavefield, atmospheric boundary layer

15. Number of Pages.
13

16. Price Code.

17. Security Classification of Report.	**18. Security Classification of This Page.**	**19. Security Classification of Abstract..**	**20. Limitation of Abstract.**
Unclassified	Unclassified	Unclassified	None

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-10:

MPL-U-3/97

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Abstract

The focus of the Marine Boundary Layer program is on the role of coherent structures in the air-sea boundary layers. As an aspect of MBL, our group was funded to make observations in the ocean mixed layer, the thermocline below, and the lower atmospheric boundary layer. Our specific objectives included the study of the wind field and wind stress and their relation to the underlying surface wavefield. The particular focus is on the role of turbulent eddies in the atmospheric boundary layer which are coherent with the underlying wavefield. This involved the study of Langmuir cells and their role in mixed layer evolution. Also, the study of thermocline shears, including those not forced by local winds, and their role in the entrainment deepening of the mixed layer were also studies. These studies took place during the course of two cruises on the Research Platform FLIP, in winter-spring 1995 The first experiment was conducted 35 km west of Point Arguello, CA, in 1 km water. The site was in a semi-permanent offshore jet, with strong steady currents toward the west-northwest.

Research Summary

The focus of the Marine Boundary Layer program is on the role of coherent structures in the air-sea boundary layers. As an aspect of MBL, our group was funded to make observations in the ocean mixed layer, the thermocline below, and the lower atmospheric boundary layer. Our specific objectives included:

- The study of the wind field and wind stress and their relation to the underlying surface wavefield. The particular focus is on the role of turbulent eddies in the atmospheric boundary layer which are coherent with the underlying wavefield (Karl Rieder, Ph. D. 1995)
- The study of Langmuir cells and their role in mixed layer evolution (Jerome Smith).
- The study of thermocline shears, including those not forced by local winds, and their role in the entrainment deepening of the mixed layer (Robert Pinkel and Matthew Alford).

These studies took place during the course of two cruises on the Research Platform FLIP, in winter-spring 1995 (Fig. 1). The first experiment was conducted 35 km west of Point Arguello, CA, in 1 km water. The site was in a semi-permanent offshore jet, with strong steady currents toward the west-northwest.

In spite of the mid-winter (15 Feb. - 14 March) setting, glassy calm conditions were found during the first half of the experiment. Typical winter conditions (10-20 m s^{-1}) prevailed during the second half of the cruise (Fig. 2, 3). The second experiment was staged off the coast of Monterey, CA in April-May 1995. All of the sensors operating in leg 1, with the exception of a profiling CTD system, were operated in leg II as well. In addition, significant additional atmospheric and biological sensors were added, under programs conducted by Drs. Carl Friehe, Jim Edson, Dave Checkley and others (Fig. 4). A list of the sensors operated by our group is presented in the Table.

Our specific technical tasks for MBL were:

1. To create a 220 kHz sector scan Doppler sonar system for operation in conjunction with a pre-existing 195 kHz instrument. The concept was to mount one instrument at mid-depth on FLIP's hull and the second near FLIP's stern (~ 85 m depth). With the fans of both instruments oriented in a vertical plane, one could, in principle, measure components of the Reynolds stress tensor in the plane of the beams and the component of the vorticity vector normal to the plane. These are of great physical interest (Fig. 5).
2. To develop a pair of rotating mounts for our sonar systems which could be linked to FLIP's gyro-compass. The objective was to maintain the azimuthal orientation of the various sonar systems on FLIP even as FLIP itself rotated in response to chang-

ing wind and current. The technical challenge here was to develop a system which was accurate to .3° and yet quiet enough, acoustically, that the sonar signals would not be contained.

3. To refurbish and operate a four beam surface wave/Langmuir cell sonar array. This was mounted at mid-depth on FLIP, attached to a rotating mount to maintain beam azimuth. The system achieved ranges to 400 m with 3 m range resolution.
4. To refurbish and operate a profiling CTD system in leg I of MBL. This system incorporated high speed (3.5 m s^{-1}) computer controlled winches to repeatedly profile specially packaged Seabird SBE9 CTDs. A single unit, which profiled to 420 m every 4 min. was used in MBL I.

A separate vertically profiling Doppler sonar, termed the "Deep 8", was constructed and mounted on FLIP's stern. This measured velocity and shear in the upper 4-500 m of the ocean with 3 m vertical resolution. The Deep 8 operated throughout MBL I and II. Its development was not funded under this program.

As a general statement, all MBL instrumentation was constructed on time and within budget. All returned extensive data sets. Problems at sea were mainly associated with the "newness" of the many different instruments. This was reflected in a slow "start up" of some of the systems at the beginning of each cruise, as we learned how to operate them most effectively.

To date, considerable progress has been made in the analysis of the data. Significant findings are to follow.

Air-Sea

Drs. Rieder and Smith have successfully measured the Reynolds stress in the lower atmosphere using the sonic anemometer. Furthermore, they have been able to isolate the component of stress associated with surface wave induced atmospheric fluctuations from that due to random fluctuations. About half of the overall stress is surface wave coherent. This represents a significant technical breakthrough (achieved in conjunction with MBL investigators Carl Friehe and Jim Edson), opening the way for a new generation of air-sea studies.

Dr.. Smith used the 195 kHz sector scan in a surface scanning mode in MBL I. He was able to map Langmuir cell activity vs x,y and time over a 35° wide sector that extended to nearly 500 m. The surprising observation is the episodic appearance and disappearance of the cells.

These observations are being presented to the modeling community (Fig. 6).

Alford and Pinkel have been observing the occurrence of overturns, breaking internal waves in the upper thermocline. Combining data from the Deep 8 sonar and the profiling CTD, they have produced depth-time maps of Richardson number. Surprisingly, the occurrence of critical Richardson number is far more common than the observation of overturns. This is reminiscent of Miles 1961 statement that $Ri < 1/4$ is a necessary, but not sufficient condition, for overturning. They are in the process of quantifying various system noise effects prior to publishing these results.

At the conclusion of the MBL program, most data are in an advanced state of analysis. Support for final analysis and publication is being provided under continuing ONR grants.

	Sensors	**Experiment Leg**
Winds	Gill vane anemometer	FLIP legs 1 &2
	Sonic anemometer	FLIP leg 1
Waves	4-beam high-resolution (HR sonar array with active heading compensation)	legs 1&2
	4-wire "wave staff" array	legs 1 & 2
Mixed layer velocity fields	Horizontal Sector Scan sonar (with active heading compensation)	leg 1 only
	Vertical Dual-Sector Scan sonars (heading compensation)	leg 2 only
	Up- and Down-looking 8-beam Doppler Sonar (Janus configuration)	legs 1 & 2
Density	Automatic conductivity, Temperature, Depth profiler (SeaBird instrument, custom winch and controller)	leg 1 only

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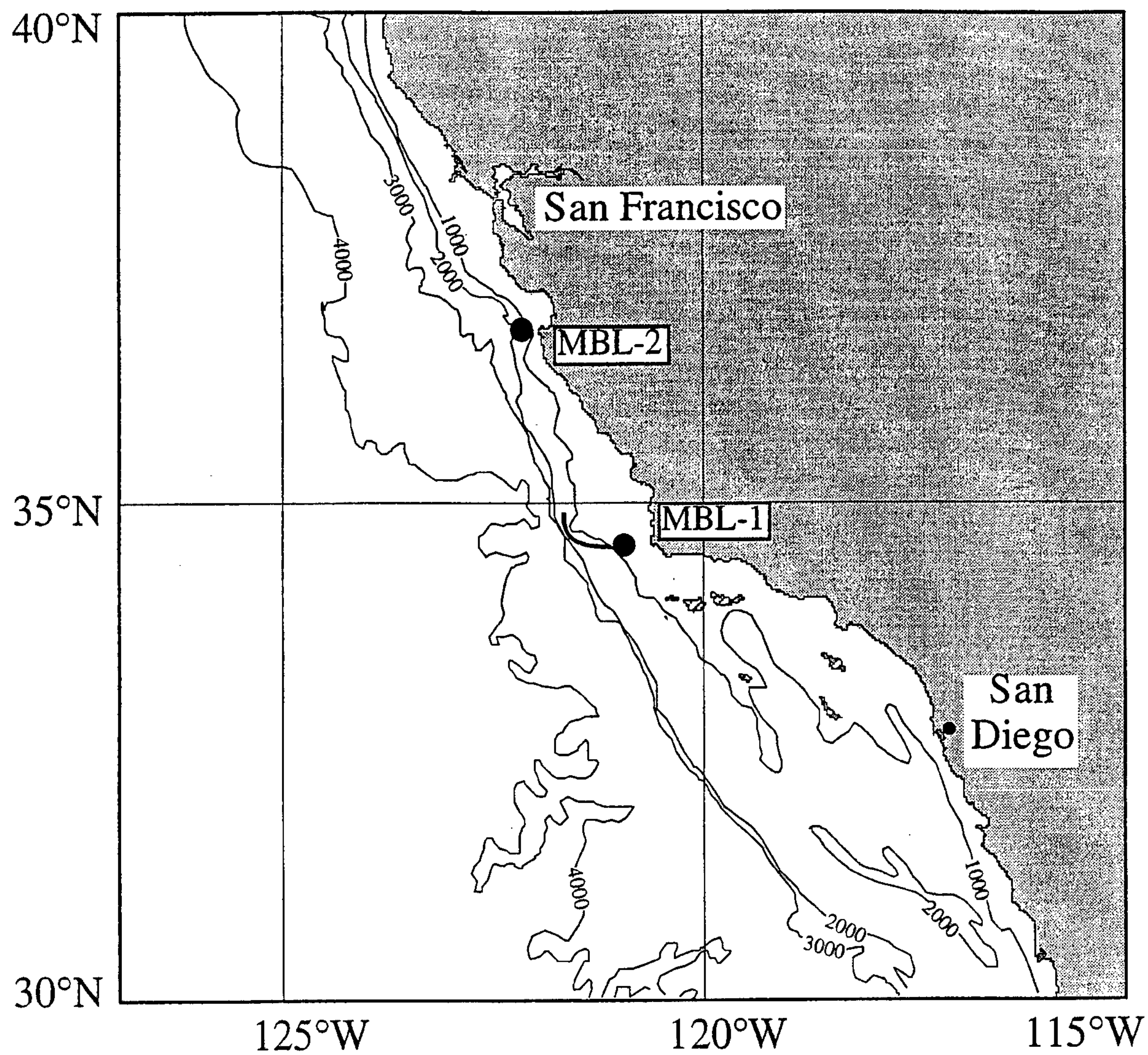

Figure 1. Sites of MBL R/P FLIP deployments for legs 1 and 2. In leg 1, FLIP was moored for 10 days, then drifted for 10 more; the spot shows the mooring location and the tail shows the drift.

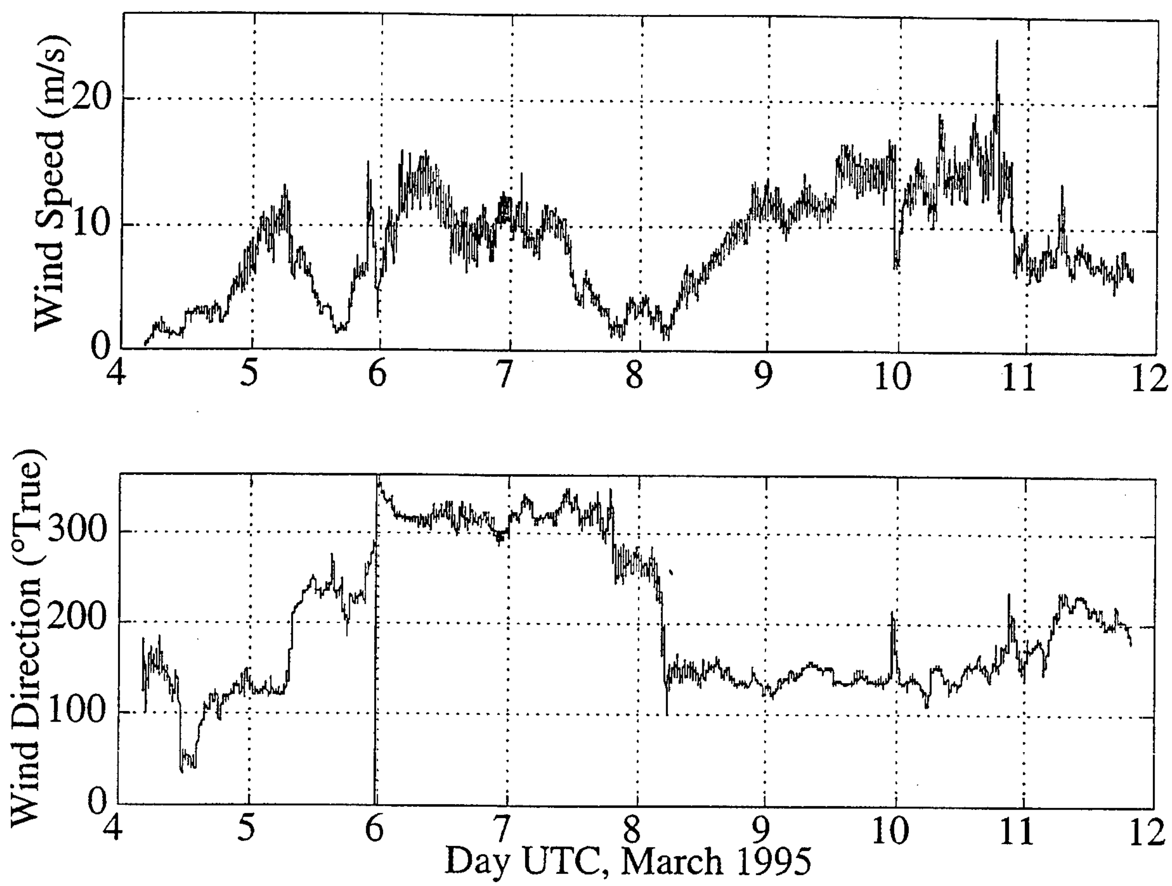

Figure 2 Windspeed and Direction over the second half of MBL-FLIP leg 1. The highest winds occurred near 1800 UTC 3/10/95, hitting 25 m/s for a few minutes.

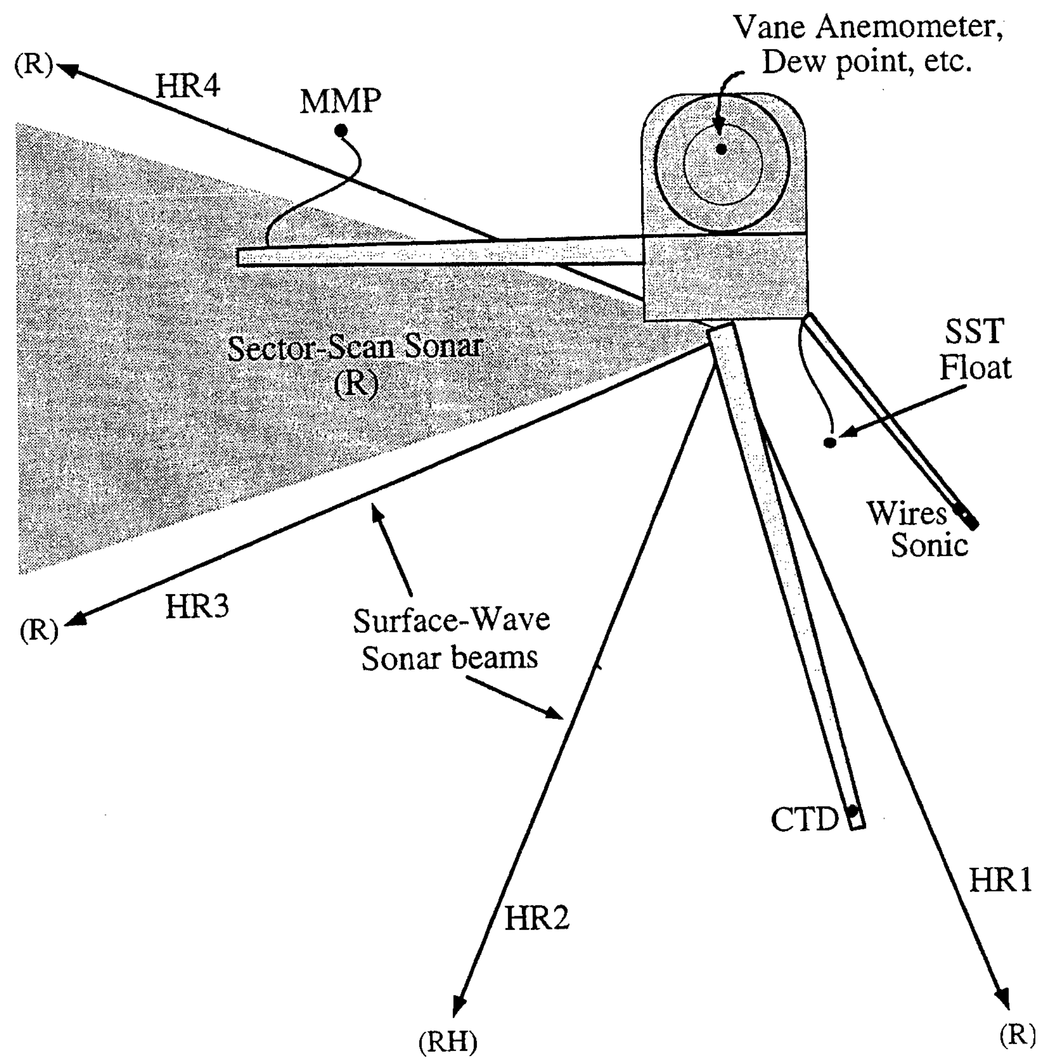

Figure 3 Plan view of R/V FLIP and instrumentation as deployed on Leg-1. Instruments with an (R) nearby indicate they are mounted on heading-compensating "rotators."

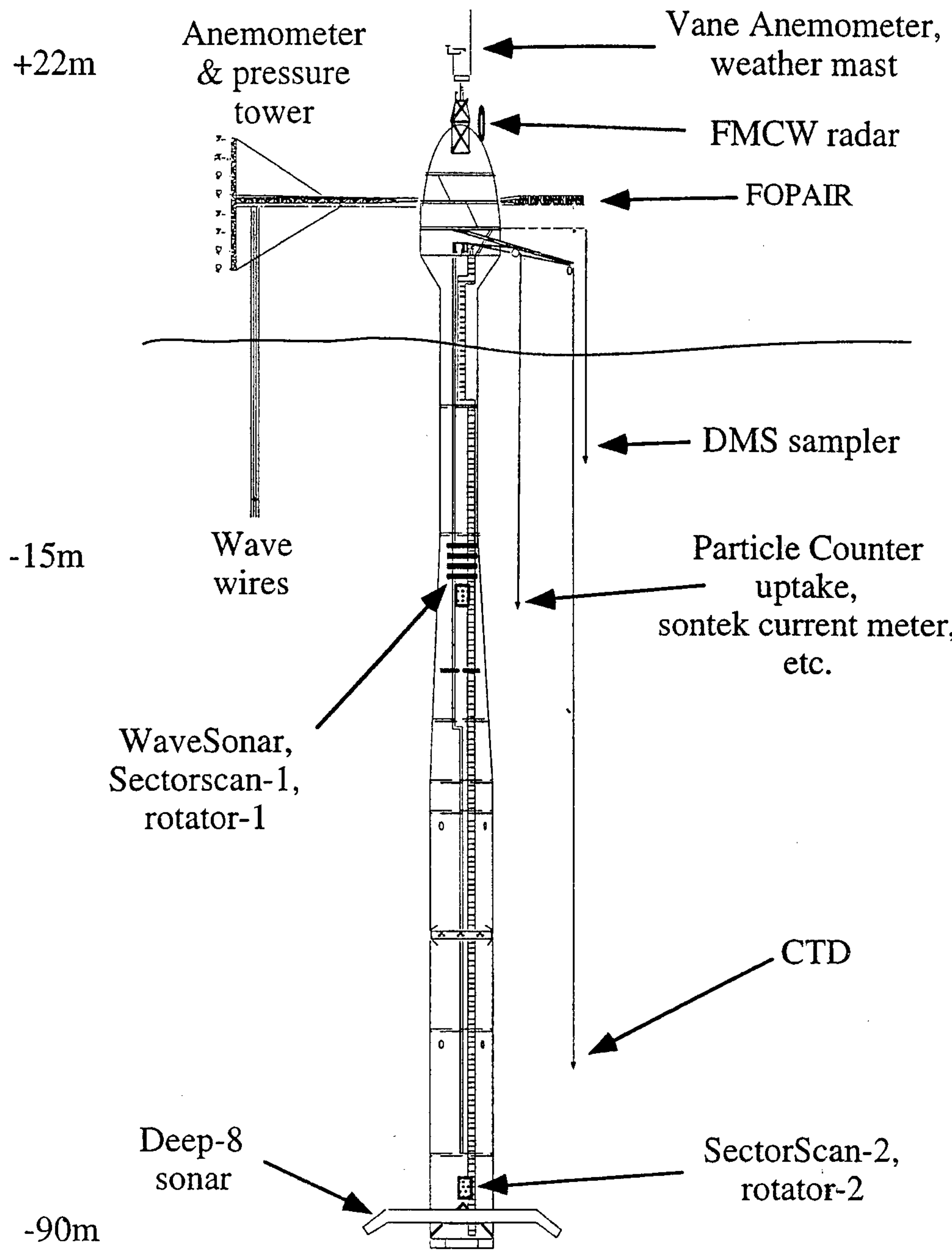

Figure 4 Profile view of R/P FLIP, showing some of the instrumentation deployed on leg 2.

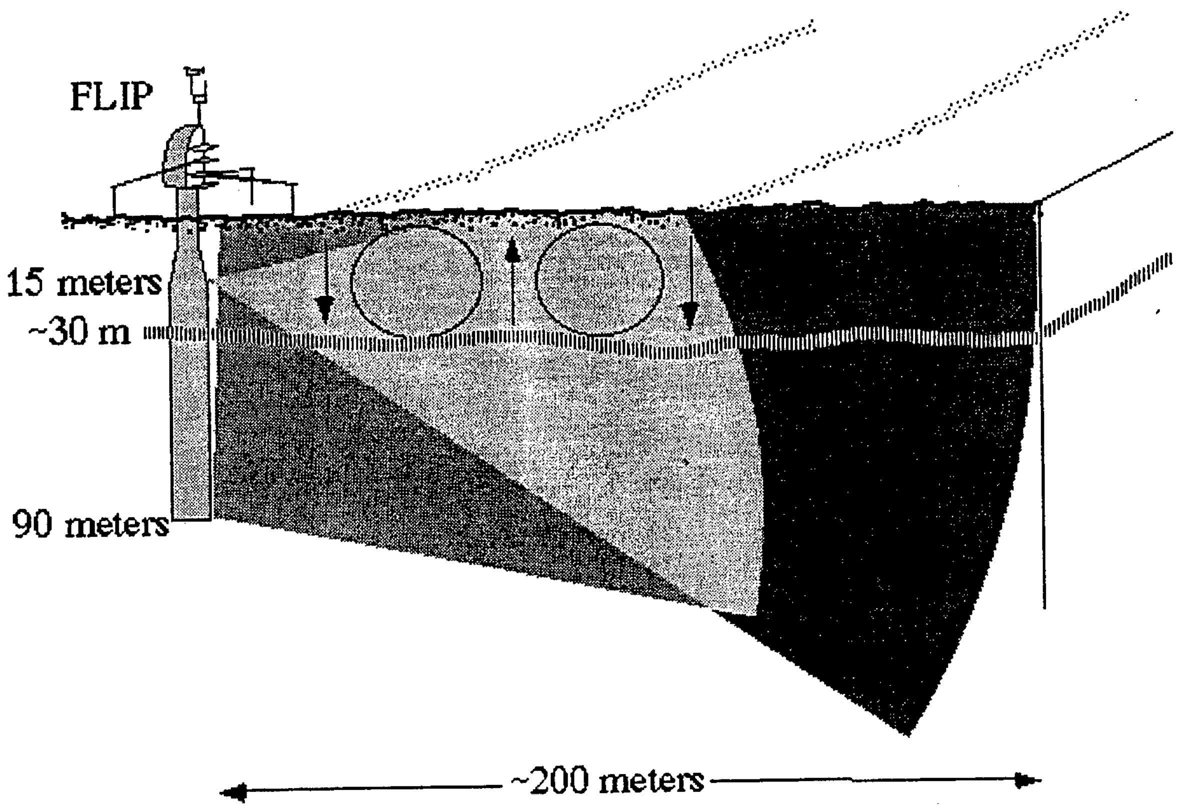

Figure 5 Schematic of the dual-sector scans, as deployed for MBL-FLIP leg-2.

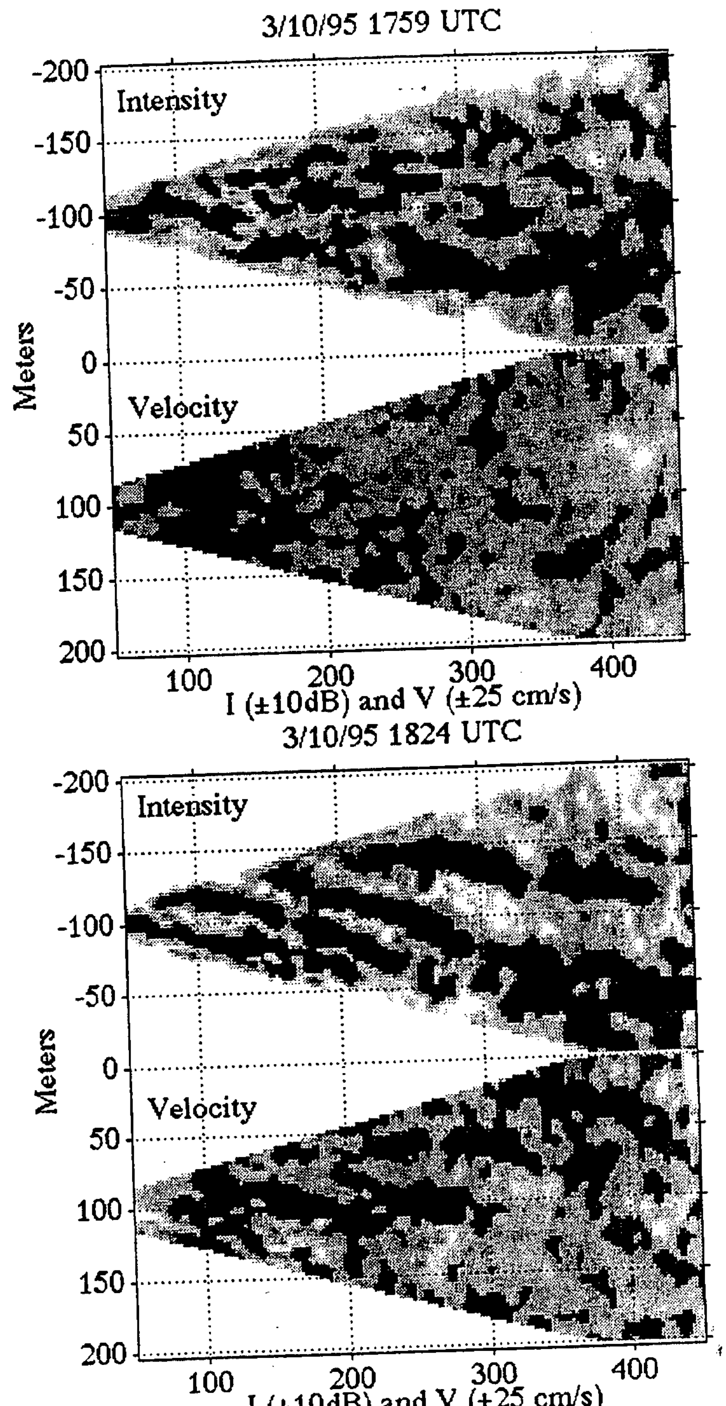

Figure 6. Very little discernible pattern at 1759 UTC, in spite of 15 to 20 m/s winds. Wind is from upper left to right. Stripes are prominent a few minutes later, at 1824 UTC near the end of the highest winds seen in the experiment. The imaging of the pattern in velocity may be hindered due to detecting only the alongwind component; hence the noise level from aliased waves could be higher. Wind is from upper left to right, parallel to the bottom edge of the wedges.

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